U.S.-CHINA JOINT RENEWABLE ENERGY PROJECTS IN THE PEOPLE'S REPUBLIC OF CHINA

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Abstract - Rapid growth in economic development coupled with the absence of an electric grid in large areas of the rural countryside have created a need for new energy sources both in urban centers and rural areas in China. The most critical need for rural electrification exists in northern and western China and in over 300 coastal islands, where 80 million rural people at the end of 1995 had no access to grid electricity. The availability of solar and wind resources tends to correlate highest with those regions of China where the population density is low and grid extension is too costly and impractical to reach the rural population. Biomass resources are also extensively available in the most populated regions of China, where as much as 15% of the primary energy requirements in the rural sector are met with wood, crop residue, and animal waste. The biomass resource is sufficient in large regions of China to support village-scale energy supply systems for both thermal and electrical energy generation. For grid-power applications, large scale wind farm development is accelerating in China, and was at the level of 58 MW of installed capacity at the end of 1996. The potential for wind power development based on accessible resources is in the range of 120 to 240 GW. The wind resource is strategically located for large wind farm development in the coastal provinces of China to supply power to large urban and industrial centers in rapidly growing regions of China. In February, 1995, the U.S. Department of Energy signed an Energy Efficiency and Renewable Energy Protocol agreement with the Chinese State Science and Technology Commission in Beijing, China. Under this agreement, the National Renewable Energy Laboratory (NREL) is providing assistance to several central government and provincial government agencies in China to develop renewable energy applications.

1. Introduction

In February, 1995, the U.S. Department of Energy (DOE) signed the Energy Efficiency and Renewable Energy Protocol agreement with the Chinese State Science and Technology Commission (SSTC) in Beijing. The agreement was part of a larger bilateral cooperation between the United States and China under a science and technology umbrella agreement managed by the DOE and the SSTC since 1979. Under the Energy Efficiency and Renewable Energy Protocol, Sino-American cooperation was established to promote the development and utilization of energy efficiency and renewable energy technologies in China in four current project annexes, each of which is assigned to a managing agency in Beijing, under the overall coordination of the SSTC.

Annex 1 establishes cooperation between the U.S. DOE and the Chinese Ministry of Agriculture (MOA) for joint activities for rural energy development and rural electrification in China. Cooperative activities are managed by the Department of Environment Protection and Energy in the MOA. A key funding partner for these activities is the State Council Office of Poverty Alleviation and Development, which funds extensive rural infrastructure development projects in China. Annex 2 establishes cooperation for renewable energy grid power development in China, with a focus on wind energy in large wind farms and village power using renewable energy hybrid systems. Cooperation is between the U.S. DOE and the Chinese Ministry of Electric Power (MOEP), managed by the Division of New Energy for Power in the Department of Hydropower Development and Rural Electrification. Annex 3 is managed by the U.S. DOE and the Chinese State Planning Commission for cooperation in the fields of energy efficiency and energy conservation, focusing on ten technology sectors for technical cooperation and business development. Annex 4 establishes cooperation for renewable energy business development between the United States and China, with the lead agency in China being the State Economic and Trade Commission, with management through the Renewable Energy Division of the Department of Energy Conservation and Resources Utilization. The U.S. DOE has delegated project management responsibilities for renewable energy projects to the National Renewable Energy Laboratory (NREL). The U.S. Export Council for Renewable Energy (ECRE) is also engaged in several business development activities in collaboration with DOE and Chinese agencies.

2. Cooperation for Rural Energy Development in the People's Republic of China

2.1 Background

The People's Republic of China is a rapidly developing and industrializing country with a population of approximately 1.2 billion people. Approximately 80% of this population lives in rural China, outside of the major urban centers of the country (Tu, 1995). In the rural regions of China the use of solar, wind, and biomass resources for general energy needs is already widespread. The potential market for the additional use of renewable energy resources for rural electrification applications is very large. For example, in the five northern and western provinces and autonomous regions of Qinghai, Tibet, Inner Mongolia, Xinjiang, and Gansu, there are a minimum of 2.2 million unelectrified households that are located in a region of China where grid power does not exist (Cabraal *et al*, 1996). For several hundred islands along the coast of China, the development of grid power in the near term is also not feasible.

In the heavily populated regions of China where grid power does exist, there are still at least 20 million households without electricity due to severe shortages of conventional electrical generating capacity based on coal-fired steam turbines and hydropower. In addition to capacity constraints, there are severe reliability problems, manifested in the form of black-outs, poor power quality, and high transmission and distribution losses. There are also increasing concerns related to the environmental impacts of coal combustion in all sectors of China's energy markets. In regions that have access to grid electricity, solar and other forms of renewables can be used to increase local electrical generating capacity in both grid-connected and off-grid applications.

2.2 Solar Home System Development in Western China

At the end of 1995, the total installed photovoltaic (PV) generating capacity in China was relatively small at about 6.6 MWp, of which 65% was used in the rapidly growing telecommunications market, 16% for household electrification, 11% for agricultural and industrial applications, and 8% for consumer applications (Wang, 1995). There is growing interest in national and provincial government agencies and in the state-owned and private business sectors of China in promoting the growth of commercial rural electrification markets using PV and other renewable energy technologies. These technologies are increasingly being recognized as a cost-effective alternative to coal-based power generation and to conventional line extension for meeting rural energy needs. The State Planning Commission in Beijing, in collaboration with additional agencies, is currently planning a rural energy initiative, called the "Brightness" Program, that will incorporate renewable energy to meet the needs of as many as 23 million people by 2010.

In June, 1995, the U.S. Department of Energy (DOE) signed a project annex under the Energy Efficiency and Renewable Energy Protocol with the Chinese Ministry of Agriculture (MOA) for joint activities for rural energy development and rural electrification in China. The first DOE and MOA joint project is in the western Chinese province of Gansu. The project is being implemented by the Solar Electric Light Fund (SELF) in Washington, D.C. and the Gansu Solar Electric Light Fund (GSELF) in Lanzhou, Gansu. The objective of this project is to provide electricity to more than 600 remote homes and schools in a two year time frame..

According to the World Bank, at the end of 1994 there were about 832,000 unelectrified households in Gansu (Cabraal *et al*, 1996). About 3,000 solar home systems had been installed in the province at the end of 1994. A typical solar home system in Gansu consists of a 20-Wp crystalline silicon PV panel, a charge controller, a 38-AH sealed lead-acid battery, two 8-W compact fluorescent lights, and necessary wiring. The system is capable of operating the fluorescent lights and a black and white television set for a few hours per day. The average retail price of such a system in Gansu is about 2,400 RMB ($290 US). Lower cost systems can be purchased in China, but are of lower quality, have more problems in the field, and exhibit shorter lifetimes.

The current project in Gansu is based mainly on cash sales to end users. The lack of credit experience in rural China necessitates the continued experimentation with installment credit terms to develop a functional credit system. The Gansu project is directed toward poor communities in rural Gansu, using limited subsidies which will be phased out during the course of the project. The planned overall recovery rate for the project is 80%, based on the 2,400 RMB sales price. The province of Gansu has among the lowest annual income levels in all of China for remote farming communities. A revolving-fund account has been set up at the Lanzhou Branch of the China Construction Bank by SELF and GSELF to leverage the project by using customer receipts to purchase more systems.

The Gansu rural electrification project is a cost-shared project with DOE providing 50% of the cost ($220K USD) and the rest is provided by Chinese partners, including: i) the Gansu Office of the Chinese State Council Office for Poverty Alleviation and Rural Development ($110K USD), ii) the Gansu Planning Commission ($44K USD), iii) the Gansu Economic and Trade Commission ($44K USD), and iv) the Gansu Solar Electric Light Fund ($22K USD). The State Council Office for Poverty Alleviation and Rural Development in Beijing is a key funding partner associated with the Ministry of Agriculture. This Office has a primary responsibility for rural development projects in China, and the Gansu project is providing a mechanism for introducing the support of renewable energy technologies into the strategic planning activities of the Office.

Three local PV system integrators in Lanzhou are responsible for system assembly and installation, for providing product warranties, and for after-sales support and training. The three companies represent three common types of business organizations in China. The Gansu PV Company is a privately owned company started by a local entrepreneur in Lanzhou. The Gansu Zi Neng Automation Engineering Company is a for-profit subsidiary of the Gansu Natural Energy Resources Institute (GNERI) in Lanzhou, which is a state-supported research institute. The Zhong Xing Electronic Instrument Company is a state-owned manufacturing company of electrical equipment, which has converted from being a military hardware supplier to providing consumer and industrial products and services. All three types of companies form an important distributor and supplier base for developing the rural electrification market in China. These companies are supplying charge controllers, compact fluorescent lights, wiring and support structures for the project.

The U.S. will supply components including polycrystalline silicon modules from Solarex, complete USSC Unikit solar home lighting systems that incorporate a-Si:H modules, and batteries from SEC Industrial Battery Corporation which are produced in a joint venture manufacturing plant in Shenzhen. Some U.S. charge controllers will also be used in the project. In Phase I of the project, 180 Solarex VLX-20 PV modules, 180 38-AH sealed lead-acid batteries, ten complete 53-Wp solar lighting kits (consisting of Solarex VLX-53 PV modules, Ananda Power charge controllers, and 65-AH batteries), and twenty USSC Unikit solar home lighting systems were delivered to the system integrators in Gansu, for installation in early 1997. The 53-Wp PV systems were installed in elementary schools in Gansu as part of an education program associated with the project.

A major barrier to the widespread deployment of photovoltaics in China has been the variable quality of modules and balance-of-system components. Quality control is being implemented through component testing and system monitoring during the Gansu project. NREL provided modules measured under standard test conditions as secondary testing standards to the three system integrators in Gansu. Chinese made charge controllers have been bench tested for safety and reliability at both GSELF and NREL. As a result of charge controller testing, recommendations were made for modifications to improve safety and reliability. System performance will be monitored throughout the course of the project with field surveys and maintenance logs.

The current project emphasis is on capacity and infrastructure building to develop a commercial market for solar home systems. Partners include the rural energy office network of the Chinese Ministry of Agriculture in Gansu to reduce the high cost of marketing, distribution, and service for solar home systems in remote areas. The rural energy offices at county, district, and township levels provide local market assistance to identify customers and help monitor the post-installation performance of systems. Experience gained in working with MOA and its extensive rural energy office network will help in the future expansion of the project to other parts of China. MOA has rural energy offices in 1,800 of the 2,300 counties in China. The MOA has plans to begin extending the Gansu solar home system project into Qinghai and Xinjiang in 1997 and is in the process of developing a 10,000 solar home system project for five provinces in western China.

An extensive training program is included in the Gansu project to train users and installers and teach marketing techniques. A two-week PV technician training seminar was held in Lanzhou starting on November, 1996 with 35 people attending from six counties. Most attendees were village technicians and rural energy officers. The seminar teaches basic principles of solar electricity as well as PV design, installation, and maintenance. As an outcome of the Gansu project, MOA is planning to establish a regional testing and training center in Lanzhou.

2.3 Hybrid Systems for Remote Households in Inner Mongolia

The Inner Mongolia Autonomous Region (IMAR) in northern and western China has a population of about 23 million people, 14 million of which are herdsmen. The land area of the region is 1.18 million km^2, and 75% of the land area consists of grasslands. The average population density in the IMAR is approximately 19 people per km^2, but in the remote rural areas, the population density is equal to or less than 3 people per km^2. The annual solar insolation in Inner Mongolia ranges between 1,280 kWh/m^2 and 1,860 kWh/m^2. Inner Mongolia also has among the highest wind resources in China.

The Inner Mongolia government has been aggressive in developing renewable energy resources for both grid-connected utility and off-grid applications. Approximately 14.5 MW of wind turbines had been installed in four wind farms in Inner Mongolia at the end of 1996. These wind farms represent 25% of the current total installed capacity in China, and they are connected to the northeast China grid. In an aggressive rural energy development program over the past ten years, more than 120,000 households have been electrified with small wind generators in the range of 100 to 300 W. In addition, more than 7000 small PV systems (total of 120 kWp) had been installed in remote households at the end of 1994.

Specific policies have been developed by Inner Mongolia to encourage the use of renewable energy technologies for rural electrification. For example, purchasers of 100-W wind generators or 16-Wp PV systems have received a 200 RMB subsidy (about $24 at today's exchange rate). Over ten years, Inner Mongolia provided 23 million RMB in subsidies for rural households to promote the initial development of a rural electrification market using renewables. An extensive infrastructure to support rural energy development in the form of a new energy service station network was also established in 56 of the 73 counties in Inner Mongolia. This infrastructure provides installation, maintenance, and sales support services for rural energy systems.

There are still more than 300,000 remote households, 1,100 villages, and 198 townships that are unelectrified in remote rural regions of IMAR. Over the next five years, the Inner Mongolia government has a goal to electrify an additional 80,000 remote households using wind, PV, and wind/PV hybrid systems. There is also a proposed plan to electrify at least 48 township centers with renewable energy central village hybrid systems, using wind/diesel and PV systems with battery storage for village hybrid system configurations. At the end of July, 1997 an additional 120 kW of PV village power installations were completed in several villages in western Inner Mongolia. The use of subsidies for rural systems is being phased out and commercialization based on market forces is being encouraged. The rural population of Inner Mongolia, consisting of herdsmen and farmers, has among the highest annual income levels of the rural populations in China.

At the request of the Inner Mongolia government during 1995, NREL, the Center for Energy and Environmental Policy (CEEP) at the University of Delaware, and the Chinese Academy of Sciences in Beijing initiated a case study analysis of rural electrification options in Inner Mongolia. The project was conducted in cooperation with the Inner Mongolia Planning Commission and the New Energy Office of Inner Mongolia, which are the two key agencies responsible for renewable energy planning in the IMAR. Other organizations participating in the project included the University of Inner Mongolia, the Inner Mongolia Polytechnic University and several local companies, providing assistance in data collection and project planning.

The first phase of the case study project consisted of levelized cost analyses of existing systems in four counties in central and northern regions of Inner Mongolia, including Si Zi Wang, Su Ni Te You, A Ba Ga, and Dong Wu Zhu Mu Qin counties. Solar and wind resource data was collected from the four counties and performance/load data was collected from 10 PV systems, 22 wind systems, and 6 PV/wind hybrid systems, which were in the 22 W to 600 W size range. Two sizes of gasoline gen-sets, common for household and ranch use, in the size range of 450 W to 500 W were examined for comparison. The results of the levelized cost of energy analyses are provided in a companion paper in this conference (Byrne *et al*, 1997), and show that PV, wind, and PV/wind hybrid systems with battery storage are more cost effective than gasoline gen-sets in serving household electrical needs and show that PV/wind hybrid systems provide a reliability greater than PV or wind alone at an intermediate cost between PV and wind stand-alone systems.

The New Energy Office of Inner Mongolia and the Inner Mongolia Planning Commission are developing plans for expanding the use of wind/PV hybrid systems by remote herdsmen families for household electrification. NREL and the CEEP at the University of Delaware are providing technical assistance to these agencies in optimizing the design of such systems. Based on annual income levels, two types of systems are receiving attention. Hybrid systems in the 400 W to 500 W range are being developed to serve household loads that include lighting, a color television set and radio, a small washing machine, and a small freezer, requiring approximately 1.2 to 1.6 kWh per day of energy. Systems consisting of a 300 Watt wind generator and 100 to 200 Watts of PV with 4.8 to 7 kWh of battery storage can generally meet this requirement. Smaller systems in the 150 W to 200 W range are being developed for intermediate income level households that provide approximately 0.6-0.7 kWh per day for household loads that do not include a freezer or washing machine. A pilot commercialization project based on remote household hybrid systems is in development to install approximately 360 units of 400-500 Watt hybrid household systems in two counties. The results of this project will be used in further planning for an 80,000 household system project over the next five years.

2.4 Biomass Collaboration

As much as 15% of China's total primary energy requirement is met by the use of biomass and bioenergy in the form of fuelwood, straws and stalks, and animal residues. Most of this is in the rural sector where this renewable energy source is used for the daily living needs of almost 900 million rural inhabitants. There is an increasing demand for "modern" fuels that are clean and efficient in their end use for cooking and heating, and as incomes rise, it appears that current forms of biomass and bioenergy use will decline and the use of LPG and kerosene will increase. Modernization of these fuels would offset increasing rural area fossil fuel use, improve the environmental performance of biofuels and retain incomes and jobs in rural areas (Sun et al, 1997 and Zhao *et al*, 1997).

The U.S. DOE, NREL and the Chinese Ministry of Agriculture are working together to evaluate the commercialization of biomass energy conversion technologies in the framework of a market-oriented development strategy. The initial phase of the cooperation is assessing the market size, technology status, and the potential for biomass power projects in China and will use this information to formulate policies and to design investment strategies for accelerating the pace of market-oriented development and implementation of biomass energy technologies. Resource availability is being characterized by developing a data base of the mainstream resources, including agricultural crop residues, animal waste, sugarcane residues, fuelwood, and urban wastes with a geographic overlay at the provincial level, and at the county level in high potential areas.

Data from research and analysis of existing demonstration projects is providing a technical status for bioenergy technologies in China. Technologies of special interest include: i) biogasification technologies at medium and large scales for combined heat and power, utilizing manures, ii) biogas technologies for treatment of urban solid wastes including landfill power generation, and iii) thermal gasification technologies for the integrated production of gas for cooking and industrial/community use, along with combined heat and power utilizing agricultural wastes. Case studies for major technologies at selected sites are being prepared that account for: i) social, energy, environmental, and developmental strategies of selected project locations, ii) attitude and capacity of local government and inhabitants to support the projects, iii) project financial and economic analysis, and iv) comparative analysis of grid-connected and stand-alone options for project structure.

A major focus is in the use of biomass at the village level for electricity production and one system that is being evaluated in detail consists of a thermal gasification unit that delivers low calorific value cooking gas directly to households. This gas which is cleaned and cooled for distribution could also be used in efficient engines to generate electricity - one concept being evaluated is the use of a Stirling motor at around the 25 kW output level. Three case studies are being performed in three provinces in detail, including Zhejiang, Shandong, and Sichuan. A techno-economic analysis of a gasification project using crop straw to produce cooking fuel at the village level has been completed for Shandong, resulting in demonstration projects in 10 villages with an additional 24 being planned.

3. Wind Farm Technical Assistance and Village Power

3.1 Background

The potential for wind generating capacity in China based on accessible resources has been estimated to be in the range of 120 to 240 GW. At the end of 1996, China had an installed capacity of about 58 MW of grid-connected wind power in 16 wind farms distributed mainly in northern China and in the coastal provinces. The Ninth Five Year Plan calls for the installation of 400 MW of wind farm capacity by the year 2000 and the Ministry of Electric Power has an internal objective of installing 1000 MW of wind farm capacity by this date. Under the Energy Efficiency and Renewable Energy Protocol, Sino-American cooperation for assisting wind farm development has been established between the U.S. Department of Energy, the American Wind Energy Association (AWEA), and the National Renewable Energy Laboratory (NREL) in the U.S. and the Ministry of Electric Power, the Electric Power Research Institute and the Hydropower Planning General Research Institute in China.

Cooperation has specifically been developed in three areas including: i) utility wind power plant analysis, including on-site wind resource measurements and assessments, ii) wind/hybrid mini-grid analysis, including on-site measurements, and iii) analysis of other wind energy technology applications. An active training program for wind energy technical personnel has been established with NREL and AWEA, in which training programs have been conducted in wind resource assessment, wind farm development and financing, and hybrid system analysis. The U.S. Environmental Protection Agency, AWEA, and the U.S. DOE are collaborating in a program of installation of anemometers and data acquisition systems at several promising wind farm sites in three provinces in China.

3.2 Wind Resource Mapping and Utility Analysis

An active collaboration has been established between the Hydropower Planning and Design General Institute in Beijing and the wind resource characterization team at NREL for introducing advanced wind resource mapping techniques to wind farm development in China. The NREL team has extensive experience in wind resource assessment, including meteorology, wind climatology, computer mapping using the ARC/INFO Geographic Information System (GIS), software development, and management of large data bases. NREL also has access to global meteorological and topographical data sets, including surface data from weather and aviation stations worldwide, upper air data taken by weather balloons, and marine data measured by ships and satellites. Cooperation with China includes specific wind mapping projects, selected by China experts and performed in collaboration with local wind farm developers, assistance in establishing state-of-the-art wind measurement stations at wind farm sites, and general technical assistance in advanced wind measurement techniques, data analysis, and quality control of wind data.

One wind mapping project has been completed for the island of Nan'ao off the coast of Guangdong province in southern China. Using topographical and meteorological data obtained from China sources, supplemented by NREL's global data base, color elevation maps and wind resource maps were generated at contour intervals of 50 meters. These maps were combined and criteria applied to identify the most favorable areas for wind farm development (and eliminate unsuitable areas), based on terrain exposure to prevailing winds, steepness of terrain, and terrain influences on wind flow. Areas of outstanding wind resource potential of 600 W/m^2 and greater were identified with terrain features suitable for wind farm development. A subsequent walk-thru of Nan'ao island with local wind experts confirmed the accuracy of the mapping analysis, also identifying areas of high potential previously overlooked. The success of the Nan'ao island wind mapping project has encouraged an expansion of the project to a broader assessment of potential wind farm locations in the three southeastern provinces of Jiangxi, Fujian, and Guangdong.

Active cooperation with China's Electric Power Research Institute for general grid-connected wind farm analysis has also been established to perform analyses, including: i) the evaluation of wind economics in terms of energy value, capacity credit, and emission reductions, ii) developing methodology and studying wind power system control and grid integration, including voltage and reactive power, transient simulation, and power quality, and iii) determining the optimum penetration of wind in a utility power system. Training of personnel from the Electric Power Research Institute and the Hydropower Planning General Research Institute in Beijing has been conducted at NREL's National Wind Technology Center, respectively, for utility-interconnected wind farm economic and operational analyses using standard utility models such as the ELFIN model, and for advanced wind resource measurement and data analysis techniques.

3.3 Renewable Energy Village Power Systems in China

The development of village power systems in China based on renewable energy technologies is at an early stage. Village power systems in the range of 5 kW to 30 kW based on PV, wind, and wind/PV hybrid technologies incorporating battery storage have been installed in Tibet, Inner Mongolia, Qinghai, and on islands of some of the coastal provinces. Autonomous wind/diesel/battery systems up to 80 kW in size have also been installed in Inner Mongolia. The largest renewable energy hybrid system is installed in Shandong Province. At the end of 1994, four village systems had been installed in Tibet with plans for three additional systems (Li *et al*, 1995) and more than twelve village systems had been installed in Inner Mongolia by the end of 1996 (Ma, 1996).

The renewable energy hybrid village power option is viable for supplying power to unelectrified villages and clusters of households in remote rural regions of China. Such systems can also supply additional electrical generating capacity for island mini-grid applications and provide supplemental power to the local grid. Renewable hybrid systems can replace diesel and gasoline gen-sets where delivered fuel prices and O&M costs are high and can be used with diesel back-up generators to extend diesel engine lifetimes and reduce O&M costs where delivered fuel costs are lower.

Under the Energy Efficiency and Renewable Energy Protocol agreement, joint cooperation has been established between NREL and China for technical assistance related to village power development in China. The initial phase of this cooperation is in the form of personnel exchanges for training in the use of hybrid village power software applications at NREL. Training of personnel from the Hydropower Planning General Research Institute and the Institute of Electrical Engineering at the Chinese Academy of Science in Beijing has been conducted by the Village Power Group, located in NREL's National Wind Technology Center. The training uses the Hybrid2 and HOMER advanced village power design and optimization simulation models developed at NREL. The training program is linked to project development in China.

4. Renewable Energy Business Development

Under the Energy Efficiency and Renewable Energy Protocol agreement with China, DOE has established cooperation with the State Economic and Trade Commission in the general area of renewable energy business development. In this cooperation, the U.S. Export Council for Renewable Energy (ECRE) and the National Renewable Energy Laboratory in the United States and the Center for Renewable Energy Development (CRED) in Beijing are collaborating on several actions, including: i) generating business relevant information in the United States and at the provincial level in China for dissemination to the renewable energy industries and other organizations in both countries (a six province business information tour was conducted by ECRE and CRED in 1996/97), ii) identifying projects of interest for U.S. industry participation, iii) general education and training (ECRE trained one person in 1997 in Washington, D.C. in policy and project development methodology), and iv) establishing an ongoing information link for disseminating project and other information through INTERNET channels. ECRE and CRED provide assistance to companies wishing to do business in China and the United States to establish joint ventures, to develop projects, acquire products, or other business activities.

The U.S. DOE also interacts with high levels in Chinese agencies to promote renewable energy development, encourage policy and project initiatives, and to play an advocacy role for U.S. renewable energy companies working in China. In collaboration with CRED, NREL has also provided technical assistance to organizations such as the World Bank and the United Nations Development Program for preparation of renewable energy case studies in China prior to project development. DOE and NREL have also provided assistance to the U.S. Export-Import Bank in development of a Credit Facility for renewable energy and energy efficiency projects in China. This credit facility has $50 million (USD) available for project financing and has received preliminary approval from the Chinese State Planning Commission, which will cooperate in project identification.

5. Conclusion

There is a large renewable energy market in China for rural electrification of remote households and villages using solar, wind, and biomass technologies, and for grid-connected renewable energy, particularly in the form of wind farms, but also for geothermal, biomass, and solar thermal electric technologies. The U.S. Department of Energy and the Chinese State Science and Technology Commission have established formal cooperation through an Energy Efficiency and Renewable Energy Protocol agreement to promote the development of renewable energy in China to serve these market sectors and to promote technology development and transfer between the U.S. and China. Several levels of cooperation have been established in the areas of rural electrification, grid-connected renewables (primarily wind farm development), policy initiatives, general business development, and financing.

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